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EMBRYOLOGY AND ITS RELATIONS[1]

By Professor ROSS G. HARRISON

OSBORN ZOOLOGICAL LABORATORY, YALE UNIVERSITY

IT is my impression that what is expected of a tiring chairman is that he inform the section upon e "state of the nation" in his branch of science. ere I to attempt this in a phrase I should say that was that of the Tower of Babel. On our program apers are listed by the hundred and are presented in arious scientific languages, only one or two of which can speak, and many speakers are talking at once, o the bewilderment of would-be listeners.

In contrast let us go back to the corresponding meeting forty years ago, when the American Society of Zoologists was called the American Morphological Society. Thirty-five papers were presented, four of them by title. A number of them dealt with the centrosome. There were several on biometry, but only one experimental study—that by Davenport on "The Rôle of Water in Growth." Dr. Minot described his newly invented rotary microtome. It is safe to say that had a Rip Van Winkle gone to sleep after that meeting and not awakened until now, he would have scarcely understood any of the papers on this year's program.

One wonders about the origin of all this present commotion, whether it does not go back to the instincts of primitive man—the nomadic hunter and the unskilled tiller of the soil. In his contact with nature he must have been impressed by the great diversity of living creatures as compared with the inorganic, and by their mysterious coming and going. Naturally he was most interested in those animals and plants that afforded food or were otherwise of practical im-

[1] Address of the retiring vice-president and chairman of the Section on Zoological Sciences, American Association for the Advancement of Science, Atlantic City, December 30, 1936.

portance, but many other creatures must have been recognized as indirectly related to his welfare and so have aroused his curiosity. Mystical notions regarding their nature were woven with practical knowledge into a sort of primitive fabric of science and religion not yet altogether disentangled.

Again in the modern development of biology whims and fancies have played a large part; else how can we account for the perverse interest in all the strange things included in the program of our meeting or typified in the appendages of the fabled paleozoic cockroach? A student once said to me that he could conceive of no greater pleasure than that of describing a new species of Staphylinid beetle. My own interest in the development of the fins of fishes was early raised to a pitch; but when I told a lady that I was writing my thesis on this subject, her reply was, "What earthly good are fins? I never eat them." To the layman such aberrations of taste are beyond comprehension. In fact, there is no easier way of holding up learning to public scorn and ridicule than to repeat the titles of Ph.D. theses.

The element of luck has also entered significantly into the development of biology, as in most other lines of human endeavor, not that it does not require intelligence to recognize luck when it comes and perseverance to gather its fruits. I recall a visit to Schermerhorn Hall, about 1910 or at least before the Drosophila visitation. Morgan waved with his hand at rows of bottles on shelves and said: "There's two years' work wasted. I've been breeding those flies for all that time and have got nothing out of it." Much progress has depended upon the fortunate findings of organisms that illustrate this or that principle clearly or such as submit to the most ruthless experimentation. Whole fields of knowledge have depended upon circumstances that are fortuitous as far as the subject itself is concerned. Take, for instance, biparental inheritance. Though it is said to have "Brought death into the World, and all our woe," think what would have been the present state of biology without it! Not to speak of the general drabness of life that would have prevailed, there would have been no genetics. We should have been robbed of the means of studying genes and might even not have suspected their existence. The chromosomes would have remained a perpetual enigma. Embryology would have had to go its way without the help of merogons and hybrids.

Some years ago I had the honor to address you as retiring president of the American Society of Zoologists. My subject was "The Return to Embryology," and my remarks included a certain amount of prophecy which has since come true. I trust, therefore, that you will grant me the indulgence of recalling some of the things then said, especially since they have not found their way into print.

Referring to the fact that all sciences have their ups and downs, it was pointed out that embryology was then (1925) in a period of depression, from which there were signs of emergence. The "organizer" had just been named. Its effects had been discovered some years before, but the importance of Spemann's work was not then so generally recognized. There were a few centers where work in experimental embryology was going on, but the flare-up and the great expectations of the 1890's and the first decade of the present century had subsided. The difficulties of understanding the development of organisms seemed to many insuperable, and no wonder.

The living embryo changes continually; its form, its mechanisms and its functions change; its parts function while changing. These transformations are themselves functions. We have, then, superposed on the ordinary functions of nutrition, respiration, protoplasmic and nervous transmission, action of internal secretions circulating in the internal medium, etc., a whole system of developmental functions, which, as far as we have been able to find out, are totally different from the former. The embryologist has, therefore, a problem of a higher order of complexity—a superproblem—to contend with than has he who directs his attention to the study of the structure or function of the finished organism.

This is usually overlooked. Embryology, from its close relation to comparative anatomy and from the employment of schemata to represent its processes, came to bear the reproach of physiologists that it was a morphological science and on that account dealt with statics and not kinetics. A moment's consideration shows this view to be altogether erroneous. The organism never reaches a state of rest until it has run its course or is securely preserved in a bottle. The physiologist accepts the finished organism as given and endeavors to find out how it works. The embryologist, on the other hand, attempts to show the origin of the mechanisms which the physiologist is content to accept ready made for study. May not the embryologist, then, return the reproach and say that the physiologist is merely looking for something easy to do?[2]

After the first harvests from the virgin field of experimental embryology had been gathered, the workers became impatient and soon landed on the barren ground of theory without the necessary factual equipment for further progress. "There was a time of discouragement. . . . The fertility of the soil seemed to have suddenly run out and tillage no longer worth while. What, more human, then, than the gold rush to genetics and general physiology?"[3] Later came another gold rush to endocrinology, now perhaps at its height.

For the embryologist those days of depression were

[2] Quoted from the 1925 manuscript.
[3] *Ibid.*

peaceful and inviting to meditation. Now in 1936 the predicted gold rush to our own territory is upon us and times are strenuous again. Our program shows two full sessions devoted to embryology, with many demonstrations, a symposium on genetics and development and many papers in other sections having a bearing on embryology. In one sense this is all satisfactory. The liaison between genetics and embryology is now established, but can we say the same of embryology and physiology? Perhaps we are still under the spell of the doctrine that more than one liaison at a time is sin.

There is a growing literature in physiological embryology, but it is still largely physiology of the embryo, as understood by the physiologist. Chemical embryology is also mainly of this kind. Our knowledge of the physical and chemical changes underlying development and differentiation is still deplorably meager.

We may distinguish in the organic world three degrees of transformation, taking place with velocities of three different orders of magnitude, and no doubt related, though precise knowledge of their relations is lacking.

(1) Those concerned with the maintenance functions of the organism—classical physiology.

(2) Those involved in the development or life history of the organism, which are in general of much lower velocity but are closely interwoven with the first group. They appear to be largely but not entirely irreversible.

(3) Those concerned with evolution or transformation of species.

Like the rate of change in the three successive categories of transformation, our knowledge of the processes involved is on a rapidly descending scale. Yet the field covered by the last has dominated biological thought for three quarters of a century! Fifty years ago Carl v. Nägeli, in his oft-cited but seldom read "Abstammungslehre,"[4] excoriated the physiologists for leaving their most difficult and crowning problem to others less competent to solve it, for, as he says, the theory of the origin of organic nature is of purely physiological character. While this phraseology would hardly be considered appropriate to-day in view of our extensive experimental morphology, Nägeli undoubtedly wished to emphasize the essentially functional nature of organic transformations, and the importance of an approach to the problem by experimental methods, which in his time, among biologists, were the possession almost exclusively of physiologists. That zoologists, botanists, anthropologists and paleontologists should have busied themselves with this great problem seemed only natural and highly desirable to Nägeli, but in their speculations they went, in his opinion, far beyond their limitations.

> The theory of evolution touches also philosophy and theology in very sensitive spots and interests the intelligent general public partly for this reason and partly because human vanity has always attached much importance to origin and relationship.
>
> On this account we have seen philosophers, theologians and, in addition, literati of all sorts and conditions take possession of the problem. This too would have been quite in order, if every one had but utilized the established results of scientific investigation for his own field and had rendered to his own circle a clarifying and instructive account of them; and if so many had not considered this field of difficult physiological problems to be a free-for-all arena for senseless argumentation.[5]

Because of early theological opposition, the theory of evolution became for its advocates a sort of religion itself, and not so long ago in this country we witnessed a veritable fundamentalist battle with theological fundamentalism on the one side and evolutionist fundamentalism on the other. The scientific investigation of evolution has suffered severely from this emotional conflict.

While it can scarcely escape any one accustomed to scientific thinking that the processes of evolution can be elucidated only by painstaking experimental work carried on over a long period of years, the short cut to knowledge by the speculative route still holds out great allurement to those whom Huxley called paper philosophers. Even with carefully controlled continuous experimentation, the enormous time involved in evolutionary changes, as compared with the life span of the individual investigator, and the difficulty of devising standards of reference that will hold constant throughout long intervals of time will render the measurement of such change very uncertain. Nevertheless, the development of modern genetics, the experimental study of the origin of mutations and the new mathematical theory of natural selection are hopeful signs of the applicability of exact methods to the study of evolutionary processes.

The difficulties of investigating embryonic development are of a different nature. The velocity of the changes is rapid enough and they may be observed repeatedly, so that experiments are readily carried out, but the scale is minute and a great variety of transformations which are inextricably interwoven are going on at the same time. It is not strange, therefore, that the experimental embryologist has gone ahead wherever a promising lead seemed to open,

[4] C. v. Nägeli, "Mechanisch-physiologische Theorie der Abstammungslehre." München u. Leipzig. R. Oldenbourg, 1884.

[5] *Op. cit.*, p. 4.

without much thought of building up a comprehensive and internally consistent system.

The reference of developmental processes to the cell was the most important step ever taken in embryology. The mutual relationship of the two primary constituents of the cell, nucleus and cytoplasm, both of which are concerned in the development of the organism, has naturally come in for much study. A number of fruitful lines of investigation bearing on this question have been followed, from which it is now generally recognized that, with few possible exceptions, the nucleus in the end controls the character of the combination. It is not to be lost sight of, however, that the nucleus can only work in cooperation with cytoplasm that is not too far removed from it systematically.

From the fact that genes, which are assigned to the nucleus, are studied mostly in relation to small mutations, it has been suggested from time to time that they are concerned only with the development of such minor characters and that the more fundamental qualities of the organism are fixed in the cytoplasm. This can hardly appeal to one who thinks the question through. The impression rests rather on the present limitations of our methods of study than on the limitation of gene action itself. We can not test by current experimental methods the effect of genes on cytoplasm of too remote origin.

The location of genes in the chromosomes, the proof of their linear order, the association of somatic characters with definite points in the chromosomes, in short, the whole development of the gene theory is one of the most spectacular and amazing achievements of biology in our times. The embryologist, however, is concerned more with the larger changes in the whole organism and its primitive systems of organs than with the lesser qualities known to be associated with genic action. As Just remarked in the symposium this morning, he is interested more in the back than in the bristles on the back and more in eyes than in eye color.

Now that the necessity of relating the data of genetics to embryology is generally recognized and the "Wanderlust" of geneticists is beginning to urge them in our direction, it may not be inappropriate to point out a danger in this threatened invasion.

The prestige of success enjoyed by the gene theory might easily become a hindrance to the understanding of development by directing our attention solely to the genom, whereas cell movements, differentiation and in fact all developmental processes are actually effected by the cytoplasm. Already we have theories that refer the processes of development to genic action and regard the whole performance as no more than the realization of the potencies of the genes. Such theories are altogether too one-sided.

Whether we accept the plasmon concept or not, we are obliged, for reasons above stated and others as well, to assign to the cytoplasm of every egg specific characters, which are different in each species of organism. In the egg there are characteristic local differentiations, which are frequently of the nature of inclusions, but after these are all accounted for, the specific character of the cytoplasm still persists in the ground substance.

Living protoplasm is a complex mixture of substances deriving its properties not merely from their chemical nature but also from their arrangement in space. Nearly all are agreed that it is to the protein constituents of protoplasm that we must look for specific characters, though there are also specific carbohydrates and lipoids.

Much has been learned about the chemistry of proteins since the turn of the century, and about their physical properties and structure. Accordingly, on a recent occasion[6] I made the attempt, taking heart from Needham and others, to refer the changes in the developing organism to the conditions imposed by the configuration of the protein molecule and its accompanying chemical and physical activities. Lest you take me to task for resorting to such crude conceptions, look at the biochemists and their zoomorphisms, their protein molecules with backbone, head, tail, limbs and even back and belly, as well as right and left sides.

It was suggested that the dipole character of these molecules would tend to orient them within the cell, possibly with respect to the point of attachment in the ovary, thus bringing to expression the primary polarity of the egg. Opposite chemical properties at the two ends would set up different reactions resulting in the formation of different substances which are carried to opposite poles by electrophoresis. Two complementary fields or material gradients would thus be formed, each extending from a region of maximum concentration at one pole to a region of minimum concentration at the other. These materials, as well as substances of genic origin entering the cytoplasm from the nucleus, would start up new reactions of varying regional intensity in the side chains of the protein molecules, according to the concentration of the primary gradients. Thus new centers and fields of chemical activity would be set up locally, and in each such region new reactions would take place with other side chains, the relative velocities of these reactions being of significance.[7] The result would be a

[6] Harvard Tercentenary Conference.

[7] R. Goldschmidt, "Physiol. Theorie d. Vererbung." Berlin, Springer, 1927.

greater and greater local diversity of action, with accompanying local differentiation of cells, as the original egg became more and more divided. This latter process has often been referred to as segregation, but it is more correct to call it localization, for it seems to be an essential of the developing organism that, while new differentiating substances are formed, all cells retain not only in their nuclei but also in their cytoplasm the same fundamental specific characters as are possessed by the egg cell. In other words, some of the specific protein molecules, with their potentialities for characteristic arrangement, remain unchanged throughout the organism.

The chemical changes may be assumed to be accompanied by changes in molecular configuration involving the constants of atomic spacing. Hence through the action of crystallization forces, new internal stresses and strains arise, which are relieved by change in shape of the cells. The movements of gastrulation, the formation of the medullary plate and its rolling up to form a tube may be ascribed to the action of such forces.

Differentiations are in a sense, then, the by-products of protoplasmic activity and are accompanied by movements involving change of form. After the chemical changes have gone to a certain point, they tend more and more to inhibit other local reactions, and finally the cell becomes so loaded with secondary material that reverse changes no longer occur. It is customary to speak of regions, cells or cell groups, in which changes have proceeded so far, as "determined." In my opinion this expression were best dropped from the language of embryology, for there is no criterion for finding out when this condition is reached, if indeed it ever is. It is never possible to know whether some new set of conditions to which a developing part may be subjected may not undo what seems to have been already done irrevocably.

The striking experiment described by Schotté at the present meeting is a case in point. Here the regenerating blastema of the limb or tail of an amphibian, when placed in the eye of a frog larva from which the lens has been removed, differentiates into a lens. Already "determined" to form cartilage, bone and muscle in a certain definite configuration, this tissue, nevertheless, under the new and radically different conditions obtaining in the eye chamber, forms a crystalline lens, a structure heretofore known to develop either directly or indirectly only out of ectodermal epithelium.

Substances that react with the living protoplasm in the above way may arise from many sources. They may diffuse into the oocyte from maternal tissues; they may arise from the genes in the nucleus; they may come from organizers, *i.e.*, from other cells in close contact with the cells affected; they may be transported in later stages through the circulating body fluids (hormones), and finally they may come from the external medium. There is no reason to think that there is any fundamental difference in the action, on the living protoplasm, of substances derived from these various sources. Much depends, however, upon the time at which the protoplasm is most sensitive to their action.[8]

The importance of substances of genic origin lies in their continuous source of supply and in their transmissibility through generations. Organizers have come into prominence through the dramatic manner in which they have demonstrated epigenetic development at a time when the tendencies of thought were in the direction of preformation. Their most striking action, still veiled in mystery, lies not in the induction of a particular organ here or there, but in making plastic material form a harmoniously constructed embryo.

The discovery that various things could be substituted experimentally for the organizer has led to the effort to isolate a pure substance that will have the same effect. Likewise the discovery, in the body fluids of insect larvae, of factors mediating the action of genes has led to the search after their chemical nature.[9] This has been stimulated further by the circumstance that certain hormones known to have definite effects on the developing organism, such as thyroxin and the sex hormones, have been isolated in pure form and are of known structural formula. The very delicate and constant effects of these substances on development have been revealed in studies from many different quarters. All this is to the good, since if one substance taking part in a reaction is known, the chances of finding out what the other substances are and what the nature of the reaction itself is are much improved. However, it must not be lost sight of that we still know practically nothing of the actual changes involved in differentiation. Genetics by itself will not solve this problem. To accomplish this will require all the ingenuity of the embryologist, using the most refined methods of physics, chemistry and general physiology, not only those of the present but many others still to be invented.

Such features as pigmentation and pigment pattern in particular demonstrate the interaction of genes and hormones. The work from the Whitman Laboratory at the University of Chicago by Lillie and collaborators shows how rates of growth, genic action, rhythms of production of hormones, threshold values, all con-

[8] F. E. Lehman has discussed this question recently in a thoughtful address. *Die Naturwissenschaften*, 24: 401–407, 1936.

[9] A. Kühn, *Wissenschaftliche Woche z. Frankfurt a. M.*, Sept. 2–9, pp. 37–48, 1934.

tribute to the establishment of plumage patterns in birds. This deserves a high place among the achievements of experimental morphogenesis. Similar work on wing patterns in the Lepidoptera by Kühn and his associates in Göttingen has yielded comparable results. Such studies lend themselves admirably to the elucidation of quantitative relationships.

The form of gourds and of many other organic structures may be referred to relative growth rates, as Sinnott has clearly shown, and those features are likewise amenable to quantitative study. Here the unit character is not a particular form itself but a relative growth rate resultant in this form. At least four different types of form determination have been recognized in this group and are independent of each other in inheritance. "The genes which control them evidently differ in the time at which the major effect is produced and in the character of the effect itself."[10]

Growth is peculiarly susceptible to conditions imposed from without, particularly food, but growth rates are dependent also upon hereditary constitution. By means of heteroplastic grafting between species having very different growth rates, it is possible to show how the growth rate of any particular organ or part may be modified by associated structures and in this way to study quantitatively the interplay between hereditary and environmental factors of development.

A new method of study of protoplasmic structure is that of x-ray diffraction, and its possible applicability to embryonic differentiation is now in the offing. This whole field is but another romantic adventure of modern physics, though not so well known as some of the others of a more speculative nature. It is only twenty-five years since v. Laue's discovery that crystals could be used as diffraction gratings for x-rays. Applied at first to the study of crystals of some of the simpler inorganic salts belonging to the regular system, the method was soon extended to more complex salts and organic compounds. Cellulose, chitin and some of the simpler or denatured proteins have also yielded to this method of attack on the problem of their atomic arrangement. Even a few of the living tissues, particularly those occurring in fibrous form, such as tendon, muscle and nerve, have given clear diffraction pictures, now that very powerful x-ray tubes with appropriate accessories, necessitating only short exposures, are available. At the meeting of the British Association last September, according to a brief report in *Nature,* Dr. Mathieu gave a paper on what might be termed x-ray cinematography, in which the change in atomic spacing occurring in the nitration of cellulose was demonstrated.[11] Surely it is not too much to hope that some of the changes taking place in embryonic differentiation may some day be similarly revealed.

I have come to the close of a rather rambling discourse and can scarcely claim proof for many of the assertions made. If they seem to be vaguely general and to lack clarity, consider the following words of Max Planck:

> We must never forget that ideas devoid of a clear meaning frequently gave the strongest impulse to the further development of science. The idea of an elixir of life or of the transmutation of base metals gave rise to the science of chemistry; that of perpetual motion to an intelligent comprehension of energy; the idea of the absolute velocity of the earth gave rise to the theory of relativity, and the idea that the electronic movement resembled that of the planets was the origin of atomic physics. These are indisputable facts, and they give rise to thought, for they show clearly that in science as elsewhere fortune favors the brave.[12]

OBITUARY

ELIHU THOMSON[1]

No obituary notice can adequately express the significance of the life and accomplishments of such a man as Elihu Thomson, nor indeed is this a serious lack, for his name and fame are already deeply rooted in our American traditions of success and of technological progress. For purposes of record, however, and as a tribute to our colleague, who was so affectionately called "The Professor" by all his friends, there is presented the following biographical notice.

Elihu Thomson was born in Manchester, England, on March 29, 1853, son of Daniel and Mary Rhodes Thomson. The family moved to America when he was five years old, settling in Philadelphia. Progressing rapidly in elementary schooling, he was ready to enter the Central High School at the age of eleven. The rules of this school, however, required him to wait until he was thirteen to enter, and he employed the intervening two years in reading and experimenting in the new and fascinating field of electricity.

Once admitted to the high school, his academic progress was rapid. Graduating at eighteen, he was immediately made an instructor in physics, then an assistant professor at twenty and a full professor at

[10] E. W. Sinnott, *The American Naturalist,* 70: 245–254, 1936.

[1] Incorporating parts of an article in *The Technology Review,* Vol. 33, January, 1931.

[11] W. T. A., *Nature,* 138: 824–825, 1936.

[12] M. Planck, "The Philosophy of Physics," p. 112. Translated by W. H. Johnston. New York, Norton and Co., 1936.

wenty-three. Even at this early age he had become a scinating lecturer on experimental electricity at the ranklin Institute, and had begun his remarkable ries of inventions which were to play so basic a part the development of the electrical industry.

The chronology of some of this earlier important ork is: 1875, demonstrated wireless waves and their ansmission to a distance through walls and floors antedating Hertz by at least a decade); 1876, demonrated his first electric generator; 1877, invented the entrifugal separator for cream and other liquids; 879, invented the 3-coil automatically regulated arc ynamo, the 3-phase generator and the system of lectric power transmission which comprises a step-up ransformer at the source of power, transmission over high tension line and a step-down transformer at he place of power consumption; 1881, invented the agnetically operated lightning arrestor; all these and ore before the age of thirty!

In 1880, Professor Thomson left the teaching career o become electrician for the American Electric Company in New Britain, Connecticut. In 1882, with his former fellow-professor at Central High School, Edwin J. Houston, he formed the Thomson-Houston Company in New Britain. A year later this new company moved to Lynn, Massachusetts, with 184 employees and a rapidly growing business in arc-lighting, electric railway and later developments. Within ten years it had grown to a concern employing 4,000 persons in Lynn and had established foreign companies, notably the great Thomson-Houston Company of England. In all these developments, Professor Thomson's right-hand colleague and close friend was Edwin W. Rice, Jr., one of his former pupils in Central High School and destined to become president of the General Electric Company.

In 1892, the Thomson-Houston Company of Lynn combined with the Edison Electric Company of Schenectady to form the General Electric Company. Professor Thomson remained at Lynn, living in Swampscott, as head of the Thomson Research Laboratories. Under the business leadership of President Charles A. Coffin and the technical leadership of Thomson and Rice, the new company grew and prospered enormously.

I pass now to two of the most important and characteristic of Professor Thomson's discoveries. The first of these is that process of electrical welding whereby the welded surfaces were fused and united by the heat developed on account of the resistance in the contact between them. This method of welding has come into enormous use in industry, and the indications are that it will be even more used in the near future. As examples in widely different fields may be mentioned the welding of seamless metal tubing, the attachment of filaments and other electrodes in incandescent lamps and vacuum tubes, and the fastening together of most of the parts of the new Ford automobile. In the former of these applications it may be interesting to know that a single manufacturer had manufactured, a few years ago, about 24,000 miles of bedstead tubing by this process in a single year.

Professor Thomson was not the first to utilize an *arc* in welding. There was some previous arc, such as Slavianoff and DeMeritens, but the DeMeritens patent, which was fundamental, was bought on advice of Professor Thomson by the Thomson Electric Welding Company in the early days and, had arc welding developed within the life of the patent, that company would have controlled the arc as well as the electric resistance welding art.

Again, one of Professor Thomson's most fundamental discoveries was the principle of dynamical repulsion between a primary and secondary coil. This can be demonstrated by a variety of interesting lecture experiments, most of which were suggested and shown first by Professor Thomson himself. This scientific observation was developed by Professor Thomson into an alternating current repulsion motor, which is nothing more nor less than our ordinary induction motor, which is in almost universal use for small single phase motors.

In connection with this discovery there is interest in the following quotation from the *Electrical World* of May 28, 1887, commenting upon this work:

> It is, as yet, too early to assign to its proper place and limit the part which the alternating current will take in the electric arts. It has started on its career with most rapid strides, and it now only remains to devise means for its accurate measurement, regulation and distribution. Certain it is that Professor Thomson's brilliant paper can not fail to act as a powerful stimulus to those whose attention is now absorbed in the direction indicated, and the fruits of which will soon be noted. We hope that at a later meeting of the Institute Professor Thomson will give to the world his practical results, which he has only hinted at in the present paper.

These practical results are now seen, for example, in probably a million induction motors in daily use.

During the years 1885–1895 Professor Thomson was busily engaged with the development of electric meters, of which more than 4,000,000 are now in operation. It is these meters which tell you and the public service corporation the amount of your monthly electric bill, and for this invention Professor Thomson was awarded the Paris Meter Prize in 1890 at a competition held after the exposition of 1889.

As early as 1890 and continued intensively for half

a dozen years thereafter were a series of brilliant experiments on high frequency alternating currents, paving the way for many of the developments in wireless and other high frequency applications which are being so actively applied at the present time. He constructed the first high frequency dynamo, operating at frequencies of 30 to 40 times as great as any previously designed, and in connection with experiments with this type of electric power he designed also the first special high frequency transformers. While working in this field he discovered a method of producing still higher frequency alternating current from a direct current arc, by shunting the arc with inductance and capacity, thus discovering the method which played such an important rôle in wireless transmission up until its virtual replacement by electronic tube devices only within the past few years. This interesting method of producing alternating currents was actually applied to wireless telegraphy by Poulsen, and is therefore generally known as the Poulsen arc. Also in connection with these high frequency investigations, he made the important discovery that the insulating power of oils at these high frequencies is very much greater than at the ordinary low commercial frequencies, if this insulating power is measured in terms of the path at which a spark will pass. Just one other item can be mentioned in connection with his high frequency work, namely, the fact that he discovered and was the first to use the method of tuning electric circuits, which is, of course, absolutely fundamental to modern electrical communication systems.

Among Professor Thomson's other contributions, mostly embodied in his more than 700 patents, the following are mentioned to illustrate the scope of his interests: "uniflow" steam engine; automobile muffler; device for automatically guiding the roll of a player-piano (invented as part of the construction of his remarkable home-made pipe organ); methods of producing optical fused quartz; stereoscopic x-ray pictures; various electrical safety devices.

Probably no other American scientist has received such recognition by learned and professional societies. He received the three most notable scientific awards of Great Britain; the Hughes Medal of the Royal Society in 1916, the Lord Kelvin Medal of the English-speaking engineering societies in 1924, and the Faraday Medal of the Institution of Electrical Engineers of England in 1927. He was decorated with the red rosette of the Legion of Honor of France in 1889, and made chevalier and officer of this body. He twice received the Grand Prix at the Paris Exposition. On his eighty-second birthday he was the second American to receive the medal of honor of the Verein Deutscher Ingenieure. In America he has twice received the John Scott Medal of the city of Philadelphia; the Elliott Cresson Gold Medal and the Franklin Medal from the Franklin Institute; the Rumford Medal of the American Academy of Arts and Sciences; the John Fritz Medal of the four founder American engineering societies.

Among Professor Thomson's official positions in professional societies are presidencies of the International Electrotechnical Commission, the International Electrical Congress and the American Institute of Electrical Engineers. He was an active member of the National Academy of Sciences, the American Philosophical Society, the Franklin Institute, the American Academy of Arts and Sciences, the American Association for the Advancement of Science and the American Chemical Society. He also took an active and official interest in the Peabody Museum of Salem and the Public Library of Swampscott.

Professor Thomson retained a life-long interest in the Massachusetts Institute of Technology, where he was a lecturer in the department of electrical engineering, life member of the corporation, acting president from 1920 to 1922 and, until his disability from illness three years ago, a faithful member of its executive committee.

In commemoration of Professor Thomson's eightieth birthday in 1933, two great meetings were held in his honor, at which his friends gathered from far and near. One of these was at M.I.T. as a symposium and exhibition of electrical developments, followed by a dinner to many hundreds of guests. The other was a neighborhood celebration by his friends and associates of Lynn and Swampscott. It is a source of gratification that these testimonials were held while Professor Thomson was yet able to participate and enjoy them. For it was in the next year that he was stricken with influenza, followed by pneumonia, which left him with the increasing affliction of asthma and heart which ultimately led to his death, in quiet and peace, on March 13, 1937.

On May 1, 1884, Professor Thomson married Mary I. Peck, of New Britain, Connecticut. They had four sons, the late Captain Stuart Thomson, who died of war injuries in 1919, Roland D. Thomson, of Schenectady, N. Y., Malcolm Thomson, of Swampscott, who is a welding engineer in the Works Fabricating department, and Donald T. Thomson, of Rye, New York. Mrs. Thomson died in 1916, and on January 4, 1923, Professor Thomson married Miss Clarissa Hovey, the daughter of Theodore Hovey, of Boston, who survives him, after their years of close companionship and the last few years of her most devoted and able care of her stricken husband.

KARL T. COMPTON

RECENT DEATHS

DR. MILTON J. GREENMAN, since 1905 director of the Wistar Institute of Anatomy, Philadelphia, died on April 7 at the age of seventy years.

DR. FREDERICK C. LANGENBERG, metallurgist, vice-president in charge of research of the United States Pipe and Foundry Company, died suddenly on April 4. He was forty-seven years old.

CHARLES H. HAUPT, of the Standard Oil Development Company, died on April 10 at the age of sixty-seven years. Mr. Haupt was formerly an assistant professor in civil engineering at the University of Pennsylvania under Professor Lewis M. Haupt, his uncle, who died a month ago.

DR. ALLAN FULSON ODELL, chemical director of the E. I. du Pont de Nemours plant at Arlington, N. J., died on April 10. He was fifty years old. From 1909 to 1913 Dr. Odell was an assistant professor in chemistry at the Louisiana State University, leaving the university to become a research chemist for Charles Pfizer and Company.

PROFESSOR DR. HEINRICH BECHHOLD, director of the Institute for Research in Colloid Chemistry at Frankfurt-a-M., died on February 18. He was the author of "Colloids in Biology and Medicine," a book which was translated by Dr. J. G. M. Bullowa.

A CORRESPONDENT writes: "Dr. Katharine Jeannette Bush, the first woman to be granted the doctor's degree in zoology at Yale University, died at Hartford, Conn., on January 19, following an incapacitating illness of nearly ten years. She had just passed her eighty-first birthday. Her professional career began in 1881, as assistant to the late Professor A. E. Verrill in studies on the marine invertebrates collected by the U. S. Fish Commission off the Atlantic Coast and in the Gulf Stream. She was later associated with the U. S. National Museum and with the Peabody Museum of Yale. Her publications consisted of systematic papers on the classification of annelids and mollusks, with descriptions of many new species. She is survived by one sister, the wife of Professor Wesley R. Coe, of Yale University."

Nature records the death of Professor J. H. F. Douvillé, formerly professor of paleontology in the National School of Mines, Paris; of Sir Albert Kitson, director of the Geological Survey of the Gold Coast in 1913–30, on March 8, aged sixty-nine years; of Professor C. J. Lewis, emeritus professor of public health in the University of Birmingham, on February 6; of Professor F. P. F. Ransom, formerly professor of pharmacology in the University of London, on February 22, aged eighty-seven years; of Sir James Currie, chairman of the governing body of the Imperial College of Tropical Agriculture, Trinidad, and director of the Empire Cotton Growing Corporation, on March 17, aged sixty-eight years, and of Professor J. A. Gilruth, formerly professor of veterinary pathology in the University of Melbourne, lately chief of the Division of Animal Health of the Commonwealth Council for Scientific and Industrial Research, on March 4, aged sixty-six years.

SCIENTIFIC EVENTS

BROADCASTS OF THE 1937 ECLIPSE

THE National Geographic Society–U. S. Navy Expedition to observe the total eclipse of June 8 from one of the Phoenix Islands will be broadcast over the coast-to-coast networks of the National Broadcasting Company. Professor S. A. Mitchell, director of the Leander McCormick Observatory of the University of Virginia, will be the leader. He will be assisted by Captain J. F. Hellweg, superintendent of the U. S. Naval Observatory, who will have charge of the Navy's participation; Dr. P. A. McNally, director of the Georgetown College Observatory; Professor F. K. Richtmyer, Cornell University; Dr. Irvine C. Gardner, National Bureau of Standards; Dr. Theodore Dunham, Jr., Mt. Wilson Observatory; John E. Willis, U. S. Naval Observatory; Charles Bittinger, Washington; Charles G. Thompson, New York; R. H. Stewart, National Geographic Society; George Hicks and Engineers Brown and Adams, of the National Broadcasting Company.

The schedule of broadcasts, three of which have already been given, follows:

March 30: George W. Hutchison, secretary, National Geographic Society, "Announcing the Eclipse Expedition."

April 10: "Science Prepares for an Eclipse." Admiral William D. Leahy, chief of Naval Operations; Dr. Lyman J. Briggs, chairman, Research Committee, National Geographic Society; and the Rev. Paul A. McNally, director, Georgetown College Observatory.

April 15: "Radio and the Eclipse." Announcer George Hicks opened the program, followed by Dr. Theodore Dunham, of Mt. Wilson Observatory, N.B.C. Engineers Brown and Adams and R. H. Stewart, National Geographic Society photographer.

April 28: "Scientists and Sailors Follow the Sun." Dr. John O. LaGorce, vice-president of the National Geographic Society, from Washington, Captain J. F. Hellweg, from Honolulu, and Dr. S. A. Mitchell, on board *S.S. Mariposa*, Los Angeles, a few hours prior to the sailing of the main scientific group.

May 6: "The Eclipse Expedition Weighs Anchor." Entire program from deck of *U.S.S. Avocet* at Honolulu. Dr. Gilbert Grosvenor, president of the National Geographic Society; Governor Poindexter, of Hawaii; Admiral Orin G. Murfin, commandant, Navy Yard, Pearl Harbor, and Dr. S. A. Mitchell. Appropriate Hawaiian music as background.

May 10: "At Sea with the Eclipse Expedition." Mid-ocean auditions from the *U.S.S. Avocet*. Members of the expedition personnel and ship's crew—preparations for "Crossing the Line."

May 16: "The Eclipse Expedition Arrives in the South Seas and Chooses Its Island." The broadcast will be direct from the island and will include general description of the landing of the expedition.

May 22: "The Eclipse Expedition at Home in the South Seas." Academic discussion by the scientific personnel and general discussion and interesting sidelights by the non-scientific personnel.

May 25: "News from Home" and "Entertainment for the Eclipse Exiles." The program opens in New York with music (seven minutes) and press radio news (five minutes). It then shifts to Washington, where eight minutes will be devoted to messages to the expedition from the National Geographic Society and to personal messages to individuals. The program will then return to New York for ten minutes of music and variety.

May 30: "The Eclipse Expedition Celebrates Decoration Day in the South Seas." Reporting news items from the expedition, interesting observations and personal messages from individual members.

June 1: Duplicate of Broadcast of May 25.

June 7: "Dress Rehearsal for the Eclipse." Roll call and a quick report from each member as to his final preparations.

June 8: Preliminary to the main program (which will follow several hours later) primarily for the purpose of establishing contact channels for the principal broadcast. Announcer George Hicks will make a general commentary, discuss the weather, etc.

June 8: "Description of the Total Eclipse of the Sun from the Area of Totality in the South Seas." Announcer George Hicks and members of the scientific staff.

June 8: "What the Eclipse Expedition Saw." Ten minutes devoted to a brief report to the National Geographic Society by Dr. S. A. Mitchell and his scientific staff, following which the program shifts to Washington, where National Geographic Society officials reply for five minutes.

APPOINTMENTS AND PROMOTIONS AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PROMOTIONS and new appointments have been made at the Massachusetts Institute of Technology as follows:

Members of the faculty promoted to the rank of full professor are: Professors Ralph D. Bennett and Edward L. Bowles, department of electrical engineering; Karl D. Fernstrom, department of business and engineering administration; Philip Franklin, department of mathematics; Murray P. Horwood, department of biology and public health; George Scatchard, department of chemistry, and Edward R. Schwarz, department of mechanical engineering.

Promoted from assistant professorships to associate professor are: Edward S. Taylor and Arthur L. Townsend, department of mechanical engineering; Raymond D. Douglass, department of mathematics; Bernard E. Proctor, department of biology and public health; John B. Wilbur, department of civil and sanitary engineering; Murray F. Gardner, Richard H. Frazier and Parry H. Moon, department of electrical engineering, and John Wulff, Wayne B. Nottingham and Nathaniel H. Frank, department of physics.

Members of the staff promoted to the rank of assistant professor are: Herbert C. Moore and Charles W. MacGregor, department of mechanical engineering; Ernest N. Gelotte, department of architecture; Robert S. Harris, department of biology and public health; Ronald H. Robnett, department of business and engineering administration; George G. Marvin and Edmund L. Gamble, department of chemistry; Arthur C. Ruge, department of civil and sanitary engineering; William M. Hall, department of electrical engineering; Paul C. Eaton, department of English; Robert H. Cameron, department of mathematics, and Morris Cohen, department of mining and metallurgy.

Promoted to the rank of instructor are: Archibald Williams, business and engineering administration; George A. Akin, chemical engineering; Edward R. Livernash, department of economics and social science; Henry E. Kiley, Leopold R. Michel, Blake Mills and Roger L. Putney, department of mechanical engineering, and Reinhardt Schuhmann, Jr., department of mining and metallurgy.

New appointments include: H. W. Fairburn as assistant professor of geology; Niels H. Larsen, instructor in architecture; Robert V. Lukes, instructor in chemical engineering; Alberto F. Thompson, Jr., instructor in chemistry, and James G. Baker, assistant director of the School of Chemical Engineering Practice.

GRANTS AWARDED BY THE AMERICAN PHILOSOPHICAL SOCIETY

THE committee on research of the American Philosophical Society, at meetings held on December 11 and February 12, made grants as follows:

Davenport Hooker, University of Pittsburgh, for functional and morphological studies of human prenatal development	$ 500
Ralph A. Beebe, Amherst College, for the direct measurement of heats of adsorption at low temperatures and the measurement of rates of adsorption under accurately controlled pressures of gas	1,000

Laurence Irving, University of Toronto, for the study of physiological adjustments of respirations in diving mammals $1,050

Robert K. Enders, Swarthmore College. The mammals of the Chiriqui region of Panama, with reference to their distribution, affinities, faunal relationships and life histories; to collect material for anatomical and embryological studies 800

Earle Radcliffe Caley, Princeton University, for the application of chemistry to archeology—the restoration and preservation, chemical examination of ancient objects, etc. 2,250

Joel Stebbins, University of Wisconsin, for the development and improvement of photo-electric amplifier; application to photometry and colorimetry of stars; study of space-reddening and of dimensions and constitution of the galaxy 1,000

Harold O. Burdick, Alfred University, for investigation of the rôle of the tubo-uterine junction to determine if this region acts like a valve which is directly or indirectly controlled by hormones 500

Murray B. Emeneau, Yale University, for the continuation of the study of Dravidian (and Munda) languages of India 2,000

James A. G. Rehn, Academy of Natural Sciences, for distributional investigation of the Orthoptera occurring in certain areas of New Mexico, Arizona, Nevada and California 500

Alexander Weinstein, Columbia University, for multiple-strand crossing over and coincidence 1,500

F. B. Isely, Trinity University, Texas, for the study of the ecology of Orthopterous insects 600

Hertha Sponer, Duke University, for investigation of absorption spectra of polyatomic molecules, especially in the photographic infra-red 800

Karl F. Herzfeld, Catholic University of America, for theoretical investigation of the absorption spectra of organic compounds 1,200

William Bell Dinsmoor, Columbia University, for a detailed study of the history, design, decoration and construction of the architectural monuments of ancient Greece in the age of Pericles 1,500

Anna R. Whiting, University of Pennsylvania, for a study of genetically different eye and body colors in mosaic males of *Habrobracon juglandis* (Ashmead) 500

Ralph E. Cleland, Goucher College, for the continuation of joint study of the cyto-genetics and phylogeny of Oenothera (Onagra), the evening primrose 1,500

Rudolf Höber, University of Pennsylvania, for the study of characteristic effects of organic ions on the secretory power of the isolated perfused liver 300

Albert T. Volwiler, Ohio University, for the preparation for publication of the correspondence between President Benjamin Harrison and James G. Blaine, his secretary of state 1,000

Enos E. Witmer, University of Pennsylvania, for the tabulation and study of the energy levels of the asymmetrical rotator 500

DEDICATION OF THE NEW BUILDING OF MELLON INSTITUTE

THE new building of Mellon Institute, which will be dedicated on May 6, was described in the issue of SCIENCE for April 9. The program in connection with the dedication ceremonies has now been announced.

At the formal dedication of the building in the afternoon of May 6 in Carnegie Music Hall, with Dr. Edward R. Weidlein, director of the institute, presiding, addresses will be given by three Nobel laureates: Dr. Irving Langmuir, chemistry; Dr. H. C. Urey, physical chemistry, and Dr. W. P. Murphy, medicine. Brief addresses will be given by Andrew W. Mellon and Richard K. Mellon, representing the founders.

The trustees' dinner will be held in the evening of the same day, among the speakers being Dr. Benjamin T. Brooks, Dr. Karl T. Compton and Dr. F. C. Whitmore. A. V. Davis, chairman of the board of the Aluminum Company of America, will be toastmaster. Trustees of the institute comprise John G. Bowman, president, Dr. Weidlein, vice-president, Henry A. Phillips, secretary-treasurer, Andrew W. Mellon and Richard K. Mellon.

There will be a symposium on "Recent Progress in Science," on the morning of Friday, May 7, in Carnegie Music Hall. The speakers will include Dr. G. O. Curme, Jr., Dr. F. B. Jewett, Sir Frederick Banting and Dr. W. W. G. Maclachlan.

The new building, which it has taken six years to complete, is to be dedicated to science and humanity in honor of Andrew W. and Richard B. Mellon, founders of the institution, who in 1911 gave support to the research fellowship system advanced by the late Robert Kennedy Duncan by establishing a specific department at the University of Pittsburgh and in 1913 placed the system on a permanent basis with the organization of Mellon Institute.

The detailed program for the dedicatory week follows:

Thursday, May 6, 9:00 A.M., assembly of out-of-town guests at the institute's new building; 10:00 A.M., preview of the building for former fellows, past and present research donors and other guests; 12:00 M., luncheon, Hotel Schenley, and luncheon sponsored by the Robert Kennedy Duncan Club for former fellows, University Club; 2:00 P.M., dedication exercises, Carnegie Music Hall; trustees' dinner, 7:30 P.M., William Penn Hotel.

Friday, May 7, 10:00 A.M., Symposium on Recent Progress of Science, Carnegie Music Hall; 12:30 P.M., luncheon for visiting scientists, University Club; 2:30 P.M., special meeting of Robert Kennedy Duncan Club, Institute Auditorium, and inspection of the new building and special exhibits; 7:00 P.M., group dinners for visiting scientists.

The new building will be open to the public on Saturday, May 8, from 10:00 A.M., to 10:00 P.M., and on Sunday, May 9, from 1:00 to 7:00 P.M.

SCIENTIFIC NOTES AND NEWS

THE American Philosophical Society will hold a general meeting in the hall of the society, Independence Square, Philadelphia, on April 22, 23 and 24. There will be five sessions for the reading of scientific papers at which the presiding officers are: President Roland S. Morris and the three vice-presidents; Drs. Edwin G. Conklin, Henry H. Donaldson and Robert A. Millikan. The Penrose Memorial Lecture on Friday evening will be given by Dr. Irving Langmuir, associate director of the Research Laboratory of the General Electric Company, who will speak on "The Surfaces of Solids and Liquids."

THE Franklin Institute of Philadelphia has awarded Franklin medals to Dr. Robert A. Millikan, director of the Norman Bridge Laboratory of Physics of the California Institute of Technology, and to Dr. Peter J. W. Debye, director of the Kaiser Wilhelm Institute of Physics in Berlin. The medals, with certificates, will be presented on the Medal Day of the institute, which has been set for May 19.

PRESENTATION of the Desmond FitzGerald Medal of the Boston Society of Civil Engineers to Professor Albert Haertlein, of the Harvard Graduate School of Engineering, was made at the annual dinner on March 17.

D. S. JACOBUS, advisory engineer to the Babcock and Wilcox Company, New York City, has been awarded the Morehead Medal of the International Acetylene Association.

DR. MILO HELLMAN, professor of dentistry at Columbia University and research associate in physical anthropology at the American Museum of Natural History, on March 15 was honored with a citation for "diligence, experience and skill, observational precision and breadth of understanding" by the Associated Foundations in the laboratory of anatomy of Western Reserve University. The citation was signed by Dr. T. Wingate Todd, for the anatomical laboratory; Dr. Wilton M. Krogman, for the anthropological division, and Dr. B. Holly Broadbent, for the Bolton Fund.

AT the annual convocation of McGill University the doctorate of laws will be conferred on Sir Josiah Stamp, the economist. Sir Josiah was last year president of the British Association for the Advancement of Science.

DR. HORACE W. STUNKARD, professor of biology at New York University, formerly corresponding secretary of the New York Academy of Sciences, has been elected to succeed the late Dr. George H. Sherwood as president of the academy.

DR. KARL S. LASHLEY, of Harvard University, was elected president of the Eastern Branch of the American Psychological Association at the spring meeting held at Vassar College on April 3. He succeeds Samuel W. Fernberger, of the University of Pennsylvania.

CHARLES M. ROGERS was elected president of the Astronomical Society of New Orleans at the annual meeting on March 31. He succeeds Dr. J. Adair Lyon.

AT the University of Cincinnati the following officers of Sigma Xi for the years 1937–38 and 1939 have been elected: *President,* Dr. R. C. Gowdy, professor of physics; *Vice-president,* Dr. H. W. Robinson, assistant professor of biochemistry, and *Secretary-Treasurer,* Dr. S. B. Arenson, associate professor of chemistry.

DR. EDITH MARION PATCH, since 1904 entomologist at the Maine Experiment Station at Orono, will retire in June.

DR. LOWELL J. REED, since 1925 professor of biostatistics at the Johns Hopkins University, has been appointed dean of the School of Hygiene and Public Health, succeeding Dr. Allen W. Freeman, who has been connected with the school since 1921 and who has been dean since 1934.

DR. ANTONIO G. SISON, professor of medicine, College of Medicine, University of the Philippines, Manila, has been appointed dean of the college to succeed Dr. Fernando Calderon, who retired in October.

DR. C. F. ROOS, professor of economics at Colorado College and research director of the Cowles Commission for Research in Economics, has resigned to accept a position as director of research with the Mercury Allied Corporation.

DR. DONALD B. GOULD, who for six years has been in charge of the department of geology and geography at Cornell College, Mount Vernon, Iowa, has been appointed to a professorship at Colorado College.

AT Princeton University, Professor William F. Thom, Jr., has been appointed to the Blair chair of geology, succeeding the late Professor Alexander E. Phillips; Associate Professor Elmer G. Butler, present chairman of the department of biology, has been named to the Class of 1877 professorship of biology, and Professor Alan W. C. Menzies has been promoted to the Russell Wellman Moore professorship of chemistry. Other promotions to professorships include Associate Professor Clodius H. Willis, of the School of Engineering, and Associate Professor N. Howell Furman, of the department of chemistry; to associate professorships Assistant Professors Gaylord P. Harnwell of the department of physics, and Richard H. Wilhelm and John C. Whitwell, of the department of

neering. Harry H. Hess, of the department of geology, has been promoted to an assistant professorship.

Members have been elected to the board of trustees of the Rockefeller Foundation as follows: President Harold Willis Dodds, of Princeton University; Dr. Douglas Southall Freeman, of Richmond, Va., president of the board of trustees of the University of Richmond and visiting professor of journalism at Columbia University; Dr. Herbert Spencer Gasser, director of the Rockefeller Institute for Medical Research, and Dr. Alfred Newton Richards, professor of pharmacology at the University of Pennsylvania.

Dean W. F. Rudd, of the Medical College of Virginia, has been placed in charge of a study of certain problems in connection with reorganization plans contemplated in the School of Pharmacy at Columbia University to be put into effect upon the retirement of the dean at the end of the present session. He plans to spend alternate weeks in New York City. Associated with him as advisers will be Dr. W. G. Crockett, president of the American Association of Colleges of Pharmacy, and Dr. Ernest Little, of Rutgers University, chairman of the executive committee of the association.

The Committee on Scientific Research of the American Medical Association announces the award of a grant to Dr. CoTui, of the Laboratory of Experimental Surgery of the New York University College of Medicine, for the study of the relation between pyrogen and the Shartzman phenomenon.

The J. T. Baker Chemical Company Analytical Research Fellowship, Eastern Division, has been awarded for the academic year 1937–38 to Robert C. Newton, for the past two years research assistant in chemistry at Princeton University. Mr. Newton will work under the direction of Professor N. H. Furman.

Professor Will E. Edington, of DePauw University, president of the Indiana Academy of Science, has appointed the following committee to cooperate with the American Association for the Advancement of Science at its winter meeting in Indianapolis: Amos W. Butler, Indianapolis, one of the founders of the academy, *chairman;* Frank B. Wade, Shortridge High School, Indianapolis, *vice-chairman;* T. E. Mason, J. J. Davis, A. A. Potter, H. R. Kraybill, T. M. Bushnell, Purdue University; R. R. Ramsey, S. S. Visher, F. Payne, C. A. Malott, Indiana University; W. M. Blanchard, Fowler D. Brooks, DePauw University; H. G. Nester, Butler University; M. S. Markle, Earlham University; S. E. Perkins, III, Indianapolis, and M. W. Lyon, Jr., South Bend.

The thirteenth William Thompson Sedgwick Memorial Lecture of the Massachusetts Institute of Technology will be delivered on April 23 by Selskar Michael Gunn, vice-president of the Rockefeller Foundation and director of public health work of the foundation in the Far East. The subject of the lecture will be "Public Health in China."

The second Hughlings Jackson Lecture of the Montreal Neurological Institute was given on April 14 by Dr. Karl S. Lashley, professor of psychology at Harvard University. He spoke on "Factors Limiting Improvement after Central Nervous Injuries."

Dean E. P. Lyon, emeritus of the Medical School of the University of Minnesota, gave an illustrated address before the Sigma Xi Club of the University of Florida on March 31. His subject was "The Medical Sciences and Education in the Soviet Union."

Dr. Herbert M. Evans, professor of anatomy and Morris Hertzstein professor of biology at the University of California Medical School, will address the Minnesota Pathological Society on April 20, on vitamins. He will discuss the same subject the following evening under the Clarence Martin Jackson Lectureship sponsored by the Phi Beta Pi medical fraternity.

Dr. Niels Bohr, Hitchcock professor this year at the University of California, Berkeley, spoke on March 19 on "Transmutations of Atomic Nuclei," under the joint auspices of the California Chapter of the Society of Sigma Xi and the department of physics of the University at Los Angeles.

The reorganized Minnesota Academy of Science will hold its fifth annual meeting at University Farm, University of Minnesota, on April 17. During the past year the academy has instituted the Junior Academy plan for the secondary schools of the state. Section programs have been arranged for the one-day session. These include the biological, physical and science education groups. Speakers and topics on the general program include from the University of Minnesota: "A Word of Welcome," Dr. Walter C. Coffey, dean of the department of agriculture; "Drought, Dust Storms and Desolation," Professor D. H. Davis; "Some Recent Advances in Clinical Physiology," Dr. Irvine McQuarrie, and "The Fate of the Indigenous," Dr. A. N. Wilcox. A public lecture has been planned for the evening session. The speaker will be Dr. H. K. Hayes, chief of the Division of Agronomy and Plant Genetics. Dr. Hayes returned recently from a year in China, where he directed the agronomic research of the country. He will speak on "Some Observations on Life in China."

The American Association of Museums will meet in New Orleans on May 3, 4 and 5. Two afternoons and two evenings will be given to the sessions of the sections; one afternoon will be free, and the last evening will be devoted to the annual dinner. The programs

of the sections are being organized by the following chairmen: Meyric R. Rogers, St. Louis, Art; Hardinge Scholle, New York, History; Katherine Coffey, Newark, Instructors; Ned Burns, Washington, National and State Parks; Sarah Newmeyer, New York, Public Relations and Radio; H. L. Story, Boston, Registrars; Robert Glenk, New Orleans, Science; Charles R. Toothaker, Philadelphia, Technical, and John W. McCabe, Cleveland, Superintendents.

A UNITED STATES CIVIL SERVICE open competitive examination has been announced for psychologist (Public Relations), at a salary of $3,800 a year in the Forest Service, U. S. Department of Agriculture, Washington, D. C. Applications must be on file not later than May 3. The work of the position is "Under general supervision, to apply the principles and techniques of psychology in a program for securing intelligent public cooperation in the protection of forest areas from fire; to determine the origin of man-caused fires; to determine current attitudes in forest areas toward fire prevention and toward the policies and practices of the Forest Service; to develop various methods of securing more effective public responsiveness to protection measures, and to evaluate the effectiveness of such methods; to make trips to field units; to supply technical psychological advice as consulting expert, and to perform other work of a related nature as assigned." Competitors will not be required to report for examination at any place, but will be rated on education and experience and on a thesis or discussion to be filed with application. The necessary application forms may be obtained from any first-class post office or from the United States Civil Service Commission, Washington, D. C.

THE Council on Physical Therapy of the American Medical Association has announced in its report of the annual meeting that grants of limited sums, to aid in research, are available to those who have problems of merit in the field of physical therapy. Application should be made to the secretary of the Council on Physical Therapy, The American Medical Association, 535 North Dearborn Street, Chicago, Ill.

DENISON UNIVERSITY at Granville, Ohio, is celebrating on April 16 the fiftieth anniversary of the founding of the Denison Scientific Association. A correspondent writes: "It is not often that a school serving no more than 850 students at the most, and definitely labeling itself a College of Liberal Arts, has been able to maintain such a vigorous interest for so long a period. A good share of the credit for this record must go to *The Journal of the Scientific Laboratories* and to the sponsors and editors of the same, who have built up, over a period of fifty-two years, a journal which goes to the far corners of the earth and brings in, in return, a wealth of scientific material and contact not often met in similar institutions." The celebration consists of bringing back to the campus alumni who have attained prominence in various scientific fields. Dr. Carey G. Croneis, professor of paleontology at the University of Chicago, is to speak on "Science and the College."

WITH a view to the encouragement of postgraduate training in scientific research, chiefly in the graduate schools of Canadian universities, the National Research Council of Canada has awarded 47 scholarships for the year 1937–38. These include three fellowships at $700 each, 12 studentships at $600, and 27 bursaries at $500, all of which will be held in departments of science at the universities. Five other scholarships, tenable in the National Research Laboratories at Ottawa, will enable the holders, all of whom have already done postgraduate research at the universities, to gain experience in the field of industrial research before engaging in commercial work. Classified according to the departments of science in which the scholarship holders will work, the awards show that chemistry in its various branches heads the list with 25, physics comes next with 12, followed by 4 in biology, 2 in genetics, and one each in botany, geology, mathematics and mechanical engineering. Applications were received from graduates of 18 Canadian universities, and awards have been made which will enable the holders to work in the graduate schools of eight different universities in Canada, namely: Dalhousie, Laval, McGill, Montreal, Queen's, Toronto, Western Ontario and Saskatchewan.

DISCUSSION

COBALT—AN ESSENTIAL ELEMENT

SOME months ago Dr. H. G. Denham, chairman of the Council of Scientific and Industrial Research of New Zealand, visited Minnesota and among other things told of the amazing success which they have had in curing "bushsickness" in domestic animals in New Zealand by the addition of traces of cobalt salts to the diet of the animals. Dr. Denham stated that alfalfa might grow luxuriantly in a cobalt deficient area, but the animals suffered severe deficiency symptoms if fed only on the forage of that area. He stated that certain "iron" salts cured the disease, whereas "iron" salts from other sources failed to cure and that the same was true for "copper" salts, and in each instance the cure had been traced to small amounts of cobalt in those salts which produced the cures.

Some weeks later at the Chicago meeting of the National Academy of Sciences, during the discussion of a paper, I commented on Dr. Denham's statements, and pointed out that this study had added cobalt to the known "essential" elements. Much to my chagrin these statements were distorted in press reports of the academy meetings, and I and my laboratories at Minnesota were credited with this discovery. In so far as I could, I attempted to correct the false report, for we have made no studies of this sort at Minnesota. Nevertheless we were given the credit in the "Summary of Science for 1936" in the columns of one of the New York daily newspapers. Accordingly, I wrote Dr. Denham and asked him to prepare a short statement outlining the scope of the work and the essential findings which could be submitted for publication in the United States in order that credit may be given where credit is due. Dr. Denham's statement, submitted in response to my request, follows.

Ross Aiken Gortner
University of Minnesota

Cobalt Investigations in New Zealand

In the course of the Liversidge Lecture delivered at the recent bi-annual meeting of the Australia and New Zealand Association for the Advancement of Science by Mr. T. Rigg, director of the Cawthron Institute, the progress of the cooperative investigations of the Department of Scientific and Industrial Research of New Zealand and the Cawthron Institute in regard to cobalt deficiency in New Zealand was reviewed.

Mr. Rigg stated that at both Morton Mains, Southland, and Glenhope, Nelson, the use of cobalt drenches supplying 8 mg cobalt per week had been completely effective in preventing and in curing sheep ailment. Furthermore, in both localities the curative properties of drench materials, which in former years had given success in the treatment of stock ailment, had been shown to be dependent not on their iron content but on a relatively high content of cobalt. Nelson soil used with success in earlier experiments at both Morton Mains and Glenhope contained 56 parts per million of cobalt. Whangarei limonite (Reyburn's), which had been shown by B. C. Aston to be so beneficial in controlling "bushsickness" on the pumice soils of the North Island, contained likewise approximately 60 parts per million of cobalt. Other drench materials, which have not proved successful in the control of stock ailment of the bushsickness type, contained relatively little cobalt. At both Glenhope and Morton Mains, acid extracts of beneficial drench materials, carefully freed from iron, gave the same results as pure cobalt salts. Recent experiments of the chemistry department of the Department of Agriculture of New Zealand had likewise shown, in the case of typical bushsickness of the North Island, that carefully purified ferric ammonium citrate was non-effective in the control of bushsickness and that cobalt salts were highly beneficial.

Much work is now in progress to determine whether there is an actual deficiency of cobalt in the pastures, soils and animal organs of the areas affected with stock ailment. Investigations are not complete, but substantial evidence is being obtained of a low cobalt status associated with affected areas. Askew and Dixon in a paper presented at the same meeting and dealing with the cobalt status of animal organs at Glenhope and Morton Mains showed conclusively that the liver, pancreas and blood of affected sheep contained very much less cobalt than corresponding organs from healthy sheep. Frequently the amount of cobalt was one tenth in the case of livers of that associated with healthy sheep, *e.g.*, cobalt content of healthy livers 0.15 to 0.25 p.p.m. compared with 0.02 p.p.m. for affected sheep. The cobalt content of livers taken from sheep drenched with cobalt salts was approximately 0.20 p.p.m. on the dry basis, corresponding closely to the cobalt content of livers from healthy sheep killed at the freezing works.

Determinations of cobalt in pastures have not proceeded far enough to enable the position to be summarized, but in the case of Glenhope pasture there is every indication that the cobalt content of affected pastures is considerably lower than that of adjoining healthy pastures. One interesting feature of the pastures investigations is the rapid intake of cobalt by pasture plants, demonstrating the possibility of using small top-dressings of soluble cobalt salts in the treatment of affected pastures. The cobalt survey of New Zealand soils made by Miss E. B. Kidson in the main has confirmed a low cobalt status of soils in association with stock ailment. One or two soils, however, gave anomalous results. These results could possibly be explained on an assumption of difference in "availability," but so far attempts to determine available cobalt in soils have not proved successful. The soil results indicate that a low cobalt status of the soil is not always a satisfactory index of the need for cobalt supplements for stock.

H. G. Denham,
Chairman, Council of Scientific and Industrial Research for New Zealand

THERMODYNAMICS AND THE RATES OF COUPLED OR REVERSED REACTIONS

Thermodynamics can give us more valuable information concerning reaction velocities than is often suspected. It is of course true that with thermody-

namics alone it is impossible to obtain even an estimate of the absolute magnitude of a reaction velocity. This apparent weakness, due to the very nature of thermodynamics, is actually a power, since it enables us to establish theorems on reaction rates which are independent of the magnitude of these rates and of the intimate reaction mechanisms. The situation is indeed quite similar with most of the other physical or chemical quantities with which thermodynamics is concerned.

A particularly simple and fruitful way of expressing the criterion for irreversible changes given by the second law of thermodynamics is to state that in the case of one single irreversible reaction, the product of affinity and reaction velocity is necessarily positive[1]:

$$A\,v > 0 \qquad (1)$$

The velocity v is the time derivative of the degree of advancement of the reaction, the affinity A is defined, for instance, as minus the partial derivative of the free energy or thermodynamic potential with respect to this degree of advancement, pressure and temperature being constant. If two independent reactions occur simultaneously in the system, the second law requires

$$A_1 v_1 + A_2 v_2 > 0 \qquad (2)$$

Two reactions are independent when, representing them by ordinary chemical formulas, it is impossible to derive one from the other by some rearrangement. Several reactions are independent when none of them can be derived from the others by means of a linear combination. Suppose now that, for some particular state of the system, we have $A_2 > 0$, $v_2 > 0$, $A_1 < 0$.

It follows from (2) that

$$v_1 < -\frac{A_2}{A_1} v_2 \qquad (3)$$

(Division by $A_1 < 0$ requires the change in the sign of the inequality). This upper limit of v_1 is positive, which shows that reaction 1 may occur in its unnatural direction. In other words, coupling of reaction 1 by reaction 2 is thermodynamically possible. The velocity of the coupled reaction must, however, remain inferior to a certain definite limit. We should add that the equality sign is also allowed in formula (3). We consider this very simple theorem as a typical piece of thermodynamic information concerning reaction rates.

Coupled or reversed reactions in biological systems have been observed and discussed by Borsook[2] and other authors. We hope that rate measurements will at some time or other be made on such systems and that our formula (3) will then be directly verified. We would also be interested in discovering a clear-cut case of coupling in some non-biological system.

A more detailed study of the thermodynamics of coupled reactions has been published elsewhere.[3]

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MAGNIFICATION OF TIME AS A RESEARCH TECHNIQUE IN THE STUDY OF BEHAVIOR

THE magnification or condensation of *space* by means of a microscope or telescope and the magnification or condensation of *energy* through thousands of mechanical and electrical devices are established scientific methods which we take for granted. It seems peculiar that the magnification or condensation of *time* has so infrequently entered into scientific concept and methodology, particularly since the means of such time magnification or condensation have been at hand and used for twenty or thirty years. We refer to ultra-rapid and infra-slow motion picture photography.

Ultra-rapid motion picture photography usually refers to pictures taken at approximately 64 exposures per second and subsequently projected at 16 to 24 exposures per second, thus affording a time magnification of four. Until recently comparatively little work has been done above this speed. The problems of film sensitivity, shutter speed, intermittent forward motion of film and of high illumination have all been obstacles. With the perfection of the revolving prism camera by Day, of stroboscopic illumination and synchronized camera by Edgerton, and of the commercial production of supersensitive film, we now have facilities for the magnification of time to effects which are higher than 200 "diameters."

As an example of the application of these new time magnification methods we have been making a study of the behavior responses of adults, infants, children and the higher primates to the sound of a pistol shot. To the naked eye this response is a confused mass of behavior. Using cameras running at a speed of 64 exposures per second it has been possible to demonstrate a clear, unmistakable, immediate, stable, reflex pattern in all the groups we have studied. This primary pattern is very rapid and is usually complete in one-half second or less. The primary response is then followed by a secondary response which is variable, differs among individuals and partakes of the nature of a socialized, conventional, learned response.

[1] Th. De Donder and P. Van Rysselberghe, "Thermodynamic Theory of Affinity. A Book of Principles." Stanford University Press, 1936. P. Van Rysselberghe: *Chemical Reviews*, 16: 37, 1935.

[2] H. F. Schott and H. Borsook, SCIENCE, 77: 589, 1933; H. Borsook, *Ergebnisse d. Enzymforschung*, 4: 1, 1935, etc.

[3] P. Van Rysselberghe, Académie royale de Belgique, Bulletins de la Classe des Sciences, December, 1936.

as opposed to the reflex nature of the primary response.

This method has made it possible to sort out the various occurrences in the seemingly very rapid responses following the gunshot. In the infant it is possible to differentiate between the primary startle pattern and the Moro reflex. In the adult we can separate the primary reflex response from the "voluntary jumping," etc. In patients showing Parkinsonian tremor the ultra-rapid photography shows a very brief cessation of the tremor after the gunshot, during which period the elements of the startle pattern appear, followed by resumption of the tremor.

While much can be done, as we have shown, with the relatively small magnification provided by a camera speed of 64 exposures per second, there is much more to be obtained at higher camera speeds. We have now begun to work with cameras capable of running as fast as 3,000 exposures per second. At present, we have results at speeds of 700 and 1,500 exposures per second. We have applied these speeds to the problem of voluntary facilitation of the reflex startle response. With the naked eye, it is impossible to separate the original response from the voluntary facilitation. At both 700 and 1,500 exposures per second, the two can be clearly separated. The primary startle pattern appears first; there is an appreciable interval; and then the "facilitation" appears as a separate response. The uses of this technique in revealing the interrelations of voluntary and involuntary response are evident. A feature of these special cameras is a timing dial included in the photographic field which may be read directly to 0.002 seconds.

The magnification of time in this fashion raises interesting perceptual problems. The dimension of time is an important determinant of the "form quality" or "gestalt" of any experience. The distortion of this one dimension may be sufficient to change the quality of the perceptual pattern. Thus, the facial elements of the startle pattern at normal speed, four times slower than normal, and fifty times slower than normal, are three qualitatively different expressions, their identity evident only if one knows the background of conditions under which the pictures were taken. The first is a "jerk," the second resembles a "hiccup," and the third a stretchy yawn. All three involve the same response with only the speed of presentation changed. Thus, the technique of temporal magnification offers a new approach to the study of time as a factor in perceptual organization.

Carney Landis

N. Y. Psychiatric Institute

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CELL INCLUSIONS IN AZOTOBACTER CHROOCOCCUM BEJ.

In a recent issue of this journal[1] I. M. Lewis, discussing the work of Jones, Löhnis and Smith, Mencl, Prazmowski and of Schmidt on the nature of the stainable granules in the cells of *Azotobacter chroococcum*, writes: "There is no indication that any of the other workers performed microchemical or solubility tests to determine whether the stainable bodies are living entities of the cell or lifeless cell inclusions which function as reserve food." He further states that his own investigations showed these to be composed of volutin.

Solely in the interest of truth and as a corroboration of the results reported by Lewis, it may be of interest here to mention a publication of the present author[2] in which, after a long series of microchemical and solubility studies, the writer concludes that "the granulations take the basic dyes and are constituted neither of fats nor glycogen, starch nor chromatine. They seem to be of a metachromatic nature." . . . and that "there is no doubt that metachromatic or, as Meyer terms them, volutine granules were found."

The reserve nature of these bodies was further demonstrated by the preesnt writer[3] by a study of their autophagy.

Augusto Bonazzi

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SCIENTIFIC BOOKS

STATISTICAL MECHANICS

Statistical Mechanics. By R. H. Fowler. 864 pp. Cambridge: at the University Press. New York: The Macmillan Company. 1937. $14.00.

The first edition of this monumental work, which appeared in 1929 and which we reviewed in this journal,[1] is already a classic in the literature of theoretical physics. So it will suffice to describe the respects in which the second edition differs from the first, both in the presentation of general principles and in the applications to particular problems. The increase in size is immediately apparent. We have always thought the author must have been almost a superman to write a volume as comprehensive as the first edition on such difficult subject-matter. Now, however, the number of pages has grown from 570 to 864, and of numbered equations from 1,607 to 2,344!

[1] J. H. Van Vleck, Science, 70: 41, 1929.

[1] Science, n. s., 85: 16, 1937.
[2] *Jour. Agr. Res.*, 4: 225–239, 1915.
[3] *Jour. Bacter.*, 6: 331–359, 1921.

As regards theoretical principles, the general method, based on contour integration and steepest descents, is the same as before, the main difference being that quantum statistics are presented from the very first, whereas until the last chapter the earlier edition used the quantal adaptation of Boltzmann statistics. For many problems, it is immaterial which version is used, but the new form is necessary, for instance, in the discussion of conducting metals, where the exclusion principle plays such an important rôle, or of chemical constants, which may involve the enumeration of nuclear spins.

In the applications, the subject-matter which is treated is distinctly more comprehensive than in the first edition. The electric and especially the magnetic susceptibilities of solids are now discussed in considerable detail, in the author's usual terse and accurate style. The reviewer has detected only one error, *viz.*, the incorrect statement on p. 480 that the apparent number of electrons in nickel is lower above the Curie point than at saturation. There is a very illuminating discussion of the conditions under which the local field is E or is instead $E + 4\pi P/3$. However, it should have been more succinctly emphasized that in polar media the statistical fluctuations may limit the rigor and applicability of the local field method. Almost a hundred new pages have been inserted on the electron theory of metals, thermionics and metallic conduction, including the rather spectacular recent work on "energy bands" and on the influence of impurities in semiconductors. An interesting section is added at the very end of the book on the timely subject of the production of extremely low temperatures by the magnetic method. The presentation of the applications covered in the earlier edition, notably astrophysical problems and the equations of state of gases and solids, has been thoroughly modernized. One usually thinks of the most striking developments of the last decade in extra-nuclear physics as in theory rather than experiment, but actually a very high percentage of the relevant experimental measurements quoted in the volume are subsequent to the first edition. On the whole, the documentation of the literature is quite complete, although occasional oversights may be noted, *e.g.*, Roebuck's determination of the second virial coefficient of helium by the porous plug experiment, as calculated by Whitelaw in *Physica*. The rapid tempo at which the material treated in the volume has been, and still is, developing both on the theoretical and experimental sides shows that even the portion of physics which is not concerned with either cosmic rays or nuclear disintegration is far from being a dead subject!

J. H. VAN VLECK

METEOROLOGY

Manual of Meteorology, Volume II, second edition. By SIR NAPIER SHAW, xlviii + 472 pp. 1936. Cambridge: at the University Press. New York: The Macmillan Company, $10.00.

THE first edition of the second volume of Shaw's great four-tome manual—the volume of facts without explanations—is far too valuable to discard, but this second edition contains so much additional material that no one who tries to keep well informed about the circulation of the atmosphere, normal, seasonal and transitory, can afford to be without it.

The book begins with discussions of a number of technical terms, so clear and detailed as to merit reading and rereading by physicists as well as meteorologists. This is followed by an 8-page discussion of units and measurement that gives much valuable and even some surprising information.

This finishes the Roman-numbered pages, a valuable treatise apart even from the rest of the volume. The first six chapters of the book proper (there are ten in all) cover, in order, solar and terrestrial radiation; distribution of land, ocean, ice, volcanoes, earthquakes, thunderstorms, magnetic lines, etc.; composition of the atmosphere; temperature of the surface air the world over and through the seasons; clouds and rainfall; pressure and winds. Much of this information is given in scores of full-page hemispherical charts.

Chapter 7, which lists a great number of reputed weather cycles and correlations, must have cost the author more labor to compile than any other in the entire manual. It deals with prodigious labors that essentially came to naught, for cycle study long has been, as presumably it long will continue to be, the fatal candle for the meteorological moth.

In Chapter 8 are discussed the several transitory variations of pressure, especially the tropical cyclone, the tornado, waterspouts and line squalls. The first portion of Chapter 9 consists of accounts of the earlier ideas of the structure of the mid-latitude cyclone, and the rest to an explanation of our present notions of this structure based on air-mass analysis. Chapter 10, the last in the book, and bringing it up to date, is a meteorological potpourri consisting of a number of interesting discussions of rather disconnected matters —the solar constant, duration of snow cover, arctic ice, the upper atmosphere, dust storms, weather in Greenland, etc. This is followed by an extensive and conveniently arranged bibliography, and that in turn by a 20-page, double-column index.

Here and there throughout the volume are delightful passages that "sample" pretty nearly pure Shaw, rather than mere meteorology, but they are none the less informative for all that and twice as interesting.

W. J. HUMPHREYS

ULTURE METHODS FOR INVERTEBRATES

lture Methods for Invertebrate Animals, a Compendium prepared Cooperatively by American Zoologists under the Direction of a Committee from Section F of the American Association for the Advancement of Science. PAUL S. GALTSOFF, FRANK E. LUTZ, PAUL S. WELCH and JAMES G. NEEDHAM, *chairman.* Ithaca, xxxi + 590. 1937. Comstock Pub. Co., $2.00.

"THIS book has been prepared as an aid to studies t require living animals in continuous supply." It s compiled by Miss Mary E. Davis, under the direcn of the four members of the committee. One hund and eighty-six collaborators have contributed one more articles, and information from other sources been reprinted. The book begins with three genl introductory chapters in which certain common thods of collecting and caring for terrestrial and uatic animals are discussed. The remainder is taken with articles which are primarily concerned with ltural methods, but often digress into other fields. r example, the brief but excellent section by R. K. Nabours gives stimulating suggestions as to favorable lines of research on grouse locusts; Dr. Libbie H. Hyman not only tells how to keep planarians under laboratory conditions, but also points out how different types may be utilized for various purposes; and J. Speed Rogers gives detailed directions for rearing various types of crane-flies from diverse habitats. Articles are arranged systematically under their respective phyla, beginning with Protozoa and ending with Ascidacea. As would be expected, considerable space is given to protozoans and arthropods.

This work will be useful for those who maintain animals for experimental work or teaching. It covers a wide range and is well organized, with cross references and a complete index. The committee which prepared it is to be congratulated on its good work. Many of the advances in scientific discovery have been made possible by the availability of dependable material for observation and experiment. The publication of culture methods by which animals may be maintained for such procedures is a valuable service.

A. S. PEARSE

SOCIETIES AND MEETINGS

THE TORONTO MEETING OF THE AMERICAN ASSOCIATION OF ANATOMISTS

A VERY successful session of the American Associan of Anatomists was held in the brisk atmosphere of ronto from March 25 to 27. The registered attennce was 303, of whom 281 were from out of town. The meeting opened with three papers on the lung, eating respectively the factors initiating respiration the embryo, the mechanical expansion of alveoli by inhalation of amniotic fluid, and the nature of the timate alveolar lining. Nine other papers were read at morning, chosen from the several fields into which atomy is now subdivided. Thereafter it was genally necessary to hold from three to six simultaneous eetings to cover the lengthy program of 150 papers d 58 demonstrations. At the evening smoker, Dr. L. Streeter described, with lantern slides, the Interational Congress of Anatomists at Milan last Septemr. Eight Americans had attended, and all presented pers. President Livini was pictured in Fascist atre, addressing the congress on the glories of Italian atomy. Everywhere one heard the Giovanezza and w the marching squadrons. The congress included memorable visit to the Carthusian monastery and the cient university of Pavia.

On the second day in Toronto, multiple sessions conued. By invitation of the president, six members the association undertook the organization of roundble conferences, dealing with special subjects as follows: "Factors in Sperm Production," P. E. Smith, Columbia University; "Structure of the Teeth," T. Wingate Todd, Western Reserve University; "Embryonic Heart," Bradley M. Patten, University of Michigan; "Present-day Trends of Investigation in the Field of Gross Anatomy," R. J. Terry, Washington University; "The Structure of Neurons and Its Functional Significance," D. M. Rioch, Harvard Medical School; "Blood Capillaries," E. V. Cowdry, Washington University. Attendance at these round-table conferences numbered from 50 to 150. All of them gave rise to a general discussion.

Three of the round tables, and three general sessions besides, occupied the second morning. The afternoon was devoted to motion-picture and other demonstrations. Then came the annual dinner of the association, in the Ball Room of the Royal York Hotel, attended by 199 persons. Led to their places by two bagpipers in Highland dress, who continued to play at intervals, the anatomists dined heartily on roast beef and Yorkshire pudding. A message from His Excellency, the Governor-General of Canada, was read as follows:

> It is with great pleasure that I welcome to Canada the American Association of Anatomists. Your coming is a further example of the fact that science knows no political frontiers. You have my best wishes for the success of your deliberations.
>
> TWEEDSMUIR

To which this reply was sent:

The American Association of Anatomists assembled at Toronto is gratified to receive Your Lordship's stimulating message. We would assure Your Excellency that Canadian and other American anatomists form what we call a syncytium.

THE SECRETARY

The Hon. and Rev. Henry John Cody, president of the University of Toronto, led the after-dinner speaking with a most cordial address of welcome, in which he described briefly the organization and character of the University of Toronto, with its 8,000 students. President Cody also called attention to the number of Canadian medical scientists, and particularly to the anatomists trained in Canada who have influenced anatomical work in the United States, mentioning especially Professors Osler and McCrae, Addison, Barker, Bensley, Chambers, Cowdry, Harvey, Macklin and McMurrich.

Dr. J. P. McMurrich, professor emeritus of anatomy in the University of Toronto, sketched biographically two pioneer contributors to anatomy in Canada: Michel Sarrazin (1659–1735), who first described the comparative anatomy of Canadian mammals in communications to the Académie Royale in Paris, and James Douglas (1800–1886), a prominent early teacher of human anatomy and the 'grand old man' of Quebec.

The president of the association, Professor F. T. Lewis, of Harvard University, then delivered the annual presidential address entitled "The Fundamentals of Cell Shape."[1] In advance of publication, he was permitted to announce the finding of Dr. J. W. Marvin, of Columbia University, that compressed lead shot of one size have an average of 14 facets—not 12—so that an accepted distinction between solid and liquid bodies in this respect disappears. With solids, such as a mass of peas, a primary contact with 12 neigh may be expected, but upon expansion to fill comple all interstices, an average of 14 facets will be es lished, as indeed might be expected from *a priori* siderations. The lecturer indulged the hope that so time there may be a symposium, with lively discuss on the neglected problems of cell shape and stru "for there are indications" which he seemed to see a ripple of interest in that direction."

The final day included five morning programs, wi able throughout. Special mention may be made of superb moving pictures of capillaries in the frog, acting to the external stimulus of a needle point by thickening of individual endothelial cells and the lo adhesion of a pair of passing red corpuscles (Zweif and Chambers, New York University).

Four afternoon papers of greater length preced adjournment. Professor Boyden, of the University Minnesota, primarily interested in Talmudic anato as a commentary on gall-bladder anomalies, explain the nature of this lore in a comprehensive histori survey. Professor Kappers, of the Institute for Br Research, Amsterdam, showed in detail the compar tive anatomy of the hypothalamic autonomic cente and Professor Ranson dealt with their functio significance. Finally Professor Bensley presented h penetrating micro-chemical studies of mitochondri dealing with the distribution of lipids in protopla and their relation to its constitution.

Professor Grant, of the University of Toronto, a his associates on the local committee, in cooperati with Professor Corner, of the University of Roches the able and experienced secretary of the associati had anticipated every need of such a convention. T first Canadian session of the Anatomists was rewar ingly alert.

CORRESPONDENT

SPECIAL ARTICLES

CORTICAL REPRESENTATION OF TACTILE SENSIBILITY AS INDICATED BY CORTICAL POTENTIALS[1]

THE observations reported below were obtained in the course of experiments directed toward a functional analysis of the somesthetic area of the cerebral cortex. It was thought that a study of the slow components of potentials which may be picked up by widely separated electrodes and which presumably result from the summed activity of cortical elements might be of value. First in cats and later in monkeys, it was found that the application of discrete tactile stimuli to a give cutaneous area produces in the cortex of the anesth tized animal well-localized surface positive wave The potentials are of such magnitude, show such reg larity over periods of time and are so decisive in t their characteristics that we have been able to empl them in mapping a cortical representation of th tactile sensibility of the body surface.

The most essential requirements for observing an recording these potentials are: (1) anesthesia of suf cient depth to reduce the Berger waves to minim frequency and size;[2] (2) the use of mechanically di

[1] For summary, see SCIENCE, April 2, 1937, Supplement, p. 10.

[1] From the Department of Physiology, Johns Hopkins University School of Medicine.

[2] It has previously been shown that surface positi activity occurs in the deeply anesthetized cat's cort

e stimuli which are brief in duraton, low in frequency and near the human threshold in intensity; (3) properly spaced thread electrodes. A cathode ray oscillograph is used for observing and recording the responses.

Stimulation is most effectively applied to hair-covered areas by a small camel's hair brush, to bare regions by a von Frey hair. These objects are mounted on a light lever of laminated wood which is rigidly attached to the moving armature of an electromagnetic device. The coils of the magnet are energized by a pulse 2 msec. in duration. This produces a regular, quick, to-and-fro movement which, at the end of the lever, amounts to a displacement of approximately 1 mm. The electrical pulse generator is a thyratron vacuum tube device possessing widely adjustable parameters and triggered by an independent circuit which also controls the x-axis unit of the cathode ray tube. Thus the pulse which activates the stimulator occurs at a given and adjustable point on the x-axis line. This part of the procedure makes it possible, provided the C.N.S. behaves with sufficient uniformity, to carry out observations with a facility comparable to that enjoyed in studies of the axon potentials of isolated nerve trunks. Experiments on 14 monkeys and 10 cats have shown this to be the case. Even when such disturbances as Berger waves interfere with the regularity and simplicity of the record, the above procedure usually enables one rapidly to determine the presence or absence of a correlated response.

The animals are anesthetized with pentobarbital sodium, chloralosan or dial. The skull is removed so as to expose the greater portion of the surfaces of one or both cortices, dural flaps are turned away and a cellophane tracing made of such landmarks as sulci and prominent pial vessels. The head of the animal is then immobilized in a Horsley-Clarke instrument constructed to carry two electrodes. This arrangement permits rapid and precise placing of the leads on the pial surface. The electrodes consist of No. 50 cotton thread drawn through sections of steel tubing and kept wet with Ringer's solution. One electrode is placed at a given point on the somesthetic area, the other on an indifferent region, *e.g.*, occipital, temporal or pre-frontal cortex. Many observations have shown us that, provided the two leads are separated by a distance of one cm or more, the position of the "indifferent" electrode has no significant effect on potentials attributable to activity under the "different" electrode. If the animal's blood temperature is maintained at a normal level, frequent wetting of the pial surface with Ringer's is unnecessary and may even cause deterioration. With repeated doses of anesthetic observations may be continued for many hours. During periods of twenty-four hours the potentials obtained in response to tactile stimulation do not progressively undergo significant reduction or changes in character. In the course of most experiments they occasionally disappear for periods of from one to five minutes, but reappear and soon regain their previous size and form.

By using the methods and principles described above we have observed that a well-localized surface positive wave regularly follows each restricted tactile stimulus. Although stimulation of a specific peripheral locus elicits positive potentials detectable over a cortical area of several square millimeters, one or more discrete spots of maximal potential are always found. The site or sites of these can be determined only by exploring the area in steps of a fraction of a millimeter. The size of a cortical area varies with the part of the periphery stimulated. In the monkey, for example, stimulation of a few hairs on the anterior aspect of the lower leg gives rise to a potential change which is restricted to a small area on the contralateral postcentral gyrus. The maximally active spot is about the size of the effective area of the electrode. The potential drops to 25 per cent. of maximum when the "different" lead is moved 0.5 mm medially or rostrally from this point, to 5 to 10 per cent. when the displacement is 1.0 mm in either of these directions. Laterally and caudally the potential decreases somewhat less abruptly. On the other hand, von Frey hair stimulation of the tip of the great toe produces potential changes within a different but larger cortical area. In this case there are two and sometimes three spots of major potential situated 1 to 5 mm from one another. One of these, usually that nearest the central sulcus, shows the shortest latency and the steepest wave front. The others have a definitely longer latency, which appears as a 2 to 5 msec. shift in the entire wave. The fact that in any cortical area the potentials decrease much more precipitously when the electrode is moved in one direction than in another indicates the part played by purely physical spread. In general our experience suggests that within any area potentials greater than 10 per cent. of the maximal are physiologically significant if they occur at distances greater than 1 mm from the maximal point. Electrotonic spread is not so easily estimated, but hardly accounts for the magnitude and behavior of certain of the propagated waves.

The amplitude of a maximal potential may be as great as 1 millivolt, but it usually lies between 100 and 300 microvolts. The rising phase occupies from 3 to 6 msec., the falling phase from 10 to 80 msec.

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n the sciatic nerve trunk is tetanized by direct electri- stimulation. See A. J. Derbyshire, B. Rempel, A. rbes and E. F. Lambert, *Am. Jour. Physiol.*, 116: 577, 6.

Under given conditions these values are quite constant. In the monkey the latencies, in milliseconds, average 15 to 20 for toes, 8 to 11 for fingers and 5 to 9 for face; in the cat the values are, approximately, 11 msec. for hindfoot, 8 for forepaw. The values may fluctuate as much as 20 per cent., but are usually constant within 5 per cent. We usually employ a stimulation frequency of one a second. The response progressively decreases in magnitude as the frequency is increased and it disappears at rates of from 12 to 15 a second. This effect is probably due to the same factors which produce the masking phenomenon described below.

A given cortical spot may yield potentials of approximately equal sizes when a discrete tactile stimulus is applied successively to different points on a restricted peripheral area. Thus brush stimulation of a few hairs within an area on the leg one inch wide and two inches long evokes potentials from a specific spot. Of great interest is the fact that these responses are attenuated or obliterated (masked) if another camel's hair brush is applied with a continuous motion anywhere else within that particular skin area. If the secondary stimulation is applied beyond the boundaries of an area represented at the cortical spot it has no masking effect.

Application of Dusser de Barenne's method of thermocoagulation[3] indicates that at least the outer layers of the cortex are not essentially concerned in the elaboration of these potentials. It is possible that only the terminations of thalamo-cortical neurons are involved, but the magnitude of the potentials, the characteristics of the spreading (*cf.* Adrian[4]) and other aspects of the responses speak against such a conclusion.

A general mapping of the entire Rolandic region and the corresponding area on the medial surface of the hemisphere can be achieved in a single experiment on a monkey by exploring with the stimulator the entire body surface each time the "different" electrode is placed on one of a series of arbitrarily selected cortical spots. Such a procedure consumes many hours, but it gives a good outline of a stable arrangement, the total representation which is revealed by these potentials. It uncovers a more detailed picture than any heretofore presented. Under the conditions of our experiments the representation appears to be confined to areas 3, 1 and 2. Up the postcentral gyrus to the hemispheral rim and then down the medial surface to sulcus cinguli the parts of the contralateral body surface are represented in an orderly sequence which roughly corresponds to that of the motor points on the precentral gyrus. Evidence has been found that in the case of the leg this sequence reflects the metameric origin of the dermatomes. No maximal potentials in response to tactile stimuli are found precentrally. Only the face has shown a definite bilateral representation.

This study, based on receptor stimulation and the related electrical response, has disclosed a cortical representation of tactile sensibility which is definitely stable. We conclude that whatever functional variations may characterize the total cortical response to tactile stimulus they are based on a highly stable anatomical substratum which is functionally demonstrable.

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[3] J. G. Dusser de Barenne and H. M. Zimmerman, *Arch. Neurol. and Psychiat.*, 33: 122, 1935.
[4] E. D. Adrian, *Jour. Physiol.*, 88: 127, 1936.

QUANTITY ULTRACENTRIFUGATION WITH INTENSE FIELDS

THE air-turbine drive[1] makes it possible to ultracentrifuge[2] large volumes of liquid as well as to carry out the analytical procedures developed by Svedberg and his coworkers. This quantity ultracentrifugation has already been used for several purposes—to concentrate the activity of yellow fever virus[4] and the pneumococcic antibodies[5] in immune horse serum and to crystallize[6] tobacco mosaic virus protein[7] directly from the juice of infected plants. Taken in conjunction with ultracentrifugal analyses it has been employed to isolate the unstable virus proteins responsible for several plant diseases[8] and to obtain in a pure state a similar substance,[9] which carries the virus activity causing infectious papillomatosis in rabbits. It is now being used routinely for the preparation of virus proteins in quantities sufficient for a detailed study of their biological, chemical and physical properties. Such ultracentrifugal preparation of proteins too unstable or present in too small amounts to be

[1] E. Henriot and E. Huguenard, *Compt. rend.*, 1389, 1925; *Jour. phys. radium*, 8: 443, 1927; J. W. Beams, *Rev. Sci. Instr.*, 1: 667, 1930; J. W. Beams and E. G. Pickels, *ibid.*, 6: 299, 1935.
[2] J. Biscoe, E. G. Pickels and R. W. G. Wyckoff, *Exp. Med.*, 64: 39, 1936; J. H. Bauer and E. G. Pickels, *ibid.*, 64: 503, 1936; R. W. G. Wyckoff and J. B. Lagsdin, *Rev. Sci. Instr.*, 8: 74, 1937.
[3] See T. Svedberg, *Naturwiss.*, 22: 225, 1934, for bibliography.
[4] J. H. Bauer and E. G. Pickels, *op. cit.*
[5] R. W. G. Wyckoff, SCIENCE, 84: 291, 1936.
[6] R. W. G. Wyckoff and R. B. Corey, SCIENCE, 84: 1936.
[7] See W. M. Stanley, *Am. Jour. Botany*, 24: 59, for bibliography.
[8] W. M. Stanley and R. W. G. Wyckoff, SCIENCE, 181, 1937.
[9] J. W. Beard and R. W. G. Wyckoff, SCIENCE, 85: 1937.

tracted by the usual chemical procedures has suggested that very probably it could isolate other biologically active substances in an unaltered condition.

Virus proteins have proved to be of exceptionally high molecular weight, and the centrifugal fields most advantageous for sedimenting and purifying them do not exceed about 50,000 times gravity. Antibodies, enzymes, protein-linked hormones and the like are smaller and therefore need higher fields for their concentration.

Using suitably shaped heads of light metal alloys we have centrifuged volumes in excess of 100 cc for as long a period as desired in fields several times those employed in the virus work. If the quantity head is made of one of the commercially available magnesium-rich alloys, the maximum field that can safely be used has been between 200,000 g and 250,000 g. Duralumin heads of the same size will run well between 250,000 g and 300,000 g; one has been operated for several hours somewhat above 350,000 g, though this is so near the bursting field that routine operation probably is impractical. In the present design of head a field of 300,000 g is attained at 60,000 r.p.m.

These fields will concentrate most proteins from aqueous or dilute salt solutions. The efficiency of concentration depends on many factors, notably the duration of the run and the viscosity, and hence the concentration and temperature, of the solution. Whether a protein sediments as a solid mass or accumulates in a liquid layer in the centrifuge tube will depend on its solubility.

In order to obtain a measure of the degree of concentration afforded by these higher fields, solutions of proteins with small sedimentation constants have been spun under otherwise comparable conditions at maximum fields of 50,000 g, 200,000 g and 250,000 g. The amount of protein in different layers was determined at the conclusion of the runs. Some results comparing the 50,000 g and the 200,000 g fields are recorded in Table I. It is apparent from these and similar data that molecules with $s > 15$ can be concentrated and those with $s > 40$ can be sedimented within a reasonable time by fields not greater than 50,000 g. Egg albumin is concentrated in the 200,000 g field and hemoglobin can be thrown down completely, though the time needed for such sedimentation is of the order of six hours.

TABLE I

CONTENTS OF LAYERS OF PROTEIN SOLUTIONS ULTRACENTRIFUGED FOR THREE HOURS

	Egg Albumin[10] $s = 3.4 \times 10^{-13}$ $M = 32{,}000$		Hemoglobin[11] $s = 4.4 \times 10^{-13}$ $M = 68{,}000$		Felton Pneumococcic Antibody[12] $s = 16 \times 10^{-13}$ cm sec^{-1} dynes^{-1} $M =$ ca 500,000	
	5×10^4 g	2×10^5 g	5×10^4 g	2×10^5 g	5×10^4 g	2×10^5 g
	Per cent.		Per cent.		Per cent.	
Top	0.8	0.6	0.9	< 0.1	0.1	< 0.1
Middle ..	0.9	1.4	1.1	< 0.1	1.0	< 0.1
Bottom .	1.2	4.8	1.9	6.0	3.8	6.0*
Original solution	0.85		1.0		1.9	

* Most of the antibody was present in the bottom of the tube as a solid precipitate.

[10] B. Sjogren and T. Svedberg, *Jour. Am. Chem. Soc.*, 52: 5187, 1930.

[11] T. Svedberg and J. B. Nichols, *Jour. Am. Chem. Soc.*, 49: 2920, 1927; T. Svedberg and A. Hedenius, *Biol. Bull.*, 66: 191, 1934.

[12] J. Biscoe, F. Hercik and R. W. G. Wyckoff, SCIENCE, 83: 602, 1936; M. Heidelberger, K. O. Pedersen and A. Tiselius, *Nature*, 138: 165, 1936; M. Heidelberger and K. O. Pedersen, *Jour. Exp. Med.*, 65: 393, 1937.

No serious new mechanical difficulties are met in working at 200,000 g. The transparent containers heretofore employed have not withstood still higher fields, but as long as a liquid is not corrosive it can be placed directly in the head and successive layers pipetted off after a run.

Details of the construction of quantity heads suitable for these higher fields as well as examples of their use in protein isolation and purification will be published later.

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BREAKING THE REST PERIOD OF THE STRAWBERRY BY LONG DAYS AT HIGH TEMPERATURES

EXPERIMENTS reported herewith indicate that long days at high temperatures may be fully effective in breaking the rest period of strawberries. The leading southern strawberry varieties when raised in the South require little or no low-temperature rest period in winter to enable them to start into vigorous growth. In contrast, northern varieties under natural field conditions require a low-temperature rest period in winter before they start vigorous growth.

During the winter of 1935–36, 10 varieties—Missionary, Southland, Blakemore, Bellmar, Dorsett, Fairfax, Narcissa, Catskill, Howard 17 (*Premier*) and Burrill—were selected to represent the most widely different growth types. Missionary, Southland and Blakemore were included to represent the southern varieties, which grow the most vigorously in short days, and Howard 17 and Burrill represented the northern varieties, which grow slowly, if at all, under short-day conditions. The other varieties are intermediate in their growth response. The plants were exposed in the greenhouse to three photoperiods (16-hour, 14-hour and normal winter days of the latitude of Beltsville, Md., ranging from 13 to 10 hours long) at each of three temperatures (70° F., 60° F., and 55° F.). The increased daily-light periods were obtained by supplemental exposure for suitable periods

at the end of each day to 500-watt Mazda lights suspended about 24 inches above the plants. In each light and temperature test there were three plant groups, one group placed under the differential light treatments on September 1; a second group brought into the greenhouse and placed under the light treatments on November 15, after having been exposed to the normal temperatures and short days of fall (about 11 hours); and a third group brought into the greenhouse and placed under the light treatment on January 1, after having had a low-temperature rest period in an unheated house. Records were taken on March 2, after the September 1 lots had been in the greenhouse 6 months, the November 15 lots 3½ months, and the January 1 lots 2 months. Leaf areas for one plant each of Blakemore and Fairfax were averaged to indicate amount of growth attained under each treatment, as an examination of all plants of all varieties showed that these two varieties were representative except in the case of Missionary under short days. Table 1 gives the average leaf area for the plants of the two typical varieties under the different light and temperature conditions on March 2.

TABLE 1

EFFECT OF VARIOUS PHOTOPERIODS AND TEMPERATURES ON LEAF AREA OF STRAWBERRY PLANTS, BELTSVILLE, MD.

Date of starting experiment	Condition of plant at start of experiment	Average leaf area on March 2, 1936					
		Day length at 70° F.			Day length at 60° F.		
		16-hr. day	14-hr. day	Normal day	16-hr. day	14-hr. day	Normal day
		Sq. cm	Sq. cm	Sq. cm	Sq. cm	Sq. cm	Sq. cm
Sept. 1	Not resting ..	934	667	426	913	460	407
Nov. 15	Resting	1,023	991	508	531	200	274
Jan. 1	Rest broken	1,023	947	668	825	581	422

At 70° F. all varieties in all three groups developed approximately the same leaf area, both in the 16-hour- and the 14-hour-day tests (the September 1 14-hour-day plants being smaller but not significantly so). In the normal-day lot, however, the September 1 and November 15 groups were similar and were still in their rest period, while the January 1 group had developed a considerably larger leaf area, indicating that its rest period had been broken. Thus, a 70° F. exposure to photoperiods of 16 and 14 hours (1) prevented a rest period in the September 1 group and (2) broke the rest period in the November 15 group. Previous exposure to low temperatures had already broken the rest period of the January 1 group.

At 60° F. the 14-hour- and normal-day lots of the September 1 group were still in their rest period, while the 16-hour lot was growing vigorously. None of the November 15 group grew vigorously at 60° F., although the 16-hour lot made some growth. Plants in the 14-hour- and normal-day lots of the November 15 group even decreased in size from loss of leaves. Each lot of the January 1 group made good growth (the normal-day plants after two months actually being as large as the September 1 normal-day lot) after six months in the greenhouse. Thus, at 60° F. under 16-hour days, (1) plants that were not in the resting condition at the start of the experiment (*i.e.*, the September 1 lot) did not undergo a rest period; and (2) plants that were in the resting condition at the start (*i.e.*, the November 15 lot) had their rest period partially broken at 60° F. under 14-hour days; (3) plants not in the resting condition (*i.e.*, September 1 lot) went into a rest period; and (4) plants in the resting condition (*i.e.*, November 15 lot) did not have their rest period broken.

The strawberry differs from many plants in that it retains its green leaves while in the resting condition. Most fruit plants lose their leaves when entering the rest period, and as a result light has no effect on the rest period. In southern states, when there is not sufficient low temperature in winter to break the rest period of fruits such as the peach, the leaves appear slowly, and after many weeks the rest period is broken and active growth is resumed. In contrast, in this experiment the strawberry plant had green leaves through which light could have an effect, and long days at high temperatures were fully effective in breaking the rest period.

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